Cereal Insect

REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 10 Period--October 1 to December 31, 1943

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The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

CORN STORAGE

Condition of Corn at Experimental Bin Sites*

Due to the demand for corn, it became necessary to release most of the experimental bins which had been under observation in various localities throughout the commercial corn area. The few remaining bins are located in Henry and Montgomery Counties, Iowa; and Yellow Medicine and Nicollet Counties, Minnesota. The regular fall samples were taken from these bins late in September.

In Henry County, Iowa, 3 of the 5 bins observed graded weevily on bran bug infestation; in Montgomery County, Iowa, 3 to 6 bins graded weevily on bran bug infestation. In Nicollet County, Minnesota, none of the 4 bins remaining at that site graded weevily, but all were infested. In Yellow Medicine County, one of six bins graded weevily and was heating because of bran bug infestation. The heavy infestation in this bin is of interest, located as it is in one of the most northerly observation points, and shows that corn in that region may at times develop dangerous insect populations, and that the low winter temperatures cannot be depended upon entirely to control insects. The sawtooth grain beetle was found in greatest abundance in most bins, except in Montgomery County where Cynaeus angustus Lec. was the dominant species.

With the exception of the few remaining bins mentioned above, the work with insects affecting stored corn may now be considered completed, and it is planned to prepare a manuscript for publication, in collaboration with the various cooperating agencies.

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* Reported by H. H. Walkden, U. S. Bureau of Entomology and Plant Quarantine.

WHEAT STORAGE

Condition of Wheat in Storage at Experimental Sites*

During October and November, the regular quarterly samples were taken from the bins on the experimental storage sites at both Jamestown, North Dakota, and Hutchinson, Kansas. Insect infestation was determined from the examination of average samples taken from each bin.

The comparative infestation at the two storage sites since the establistment of the project in 1941 is given in table 1. At Jamestown, insect populations have remained consistently at a very low level throughout the storage period, while at Hutchinson, insect infestation has been the major problem in connection with the safe storage of wheat.

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* Reported by H. H. Walkden and R. B. Schwitzgebel, U. S. Dept. of Agriculture, Bureau of Entomology and Plant Quarantine in cooperation with the Bureau of Plant Industry, Soils and Agricultural Engineering.

Table 1: -- Comparison of the insect infestation in wheat stored at Jamestown, North Dakota, and at Hutchinson, Kansas, October, 1941, to October, 1943.

Sampling period	Jamestown, North Dakota: No. bins sampled	Weevily bins (%)	Infested, not weevily (%)	Total infested (%)	Hutchinson, Kansas: No. bins sampled	Weevily bins (%)	Infested, not weevily (%)	Total infested (%)
1941								
Oct.-Nov.	139	1	18	19	144	9	31	40
1942								
Jan.-Feb.	133	1	6	7	135	16	53	69
Apr.-May	139	0	4	4	135	2	59	61
July-Aug.	142	0	6	6	124	0	43	43
Oct.-Nov.	146	0	1	1	133	58	21	79
1943								
Jan.-Feb.	152	0	0	0	144	33	21	54
Apr.-May	164	0	0.6	0.6	148	5	26	31
July-Aug.	166	0	2.5	2.5	114	60	26	86
Oct.-Nov.	132	0.8	0.8	1.6	165	46	43	89

At Jamestown, only two species were found in the November samples, namely, the rust-red grain beetle (Laemophloeus ferrugineus Steph.) and the sawtooth grain beetle (Oryzaephilus surinamensis L.). At Hutchinson, nine species of stored grain insects were found. These are listed below, together with their comparative abundance.

Species	Average number per 1000-gram sample
1. Flat grain beetle (Laemophloeus minutus Oliv.)	3.08
2. Lesser grain borer (Rhyzopertha dominica F.)	2.16
3. Rice weevil (Sitophilus oryza L.)*	1.81
4. Sawtooth grain beetle (Oryzaephilus surinamensis L.)	1.60
5. Red flour beetle (Tribolium castaneum Hbst.)	0.69
6. Long-headed flour beetle (Latheticus oryzae Waterh.)**	0.06
7. Foreign grain beetle (Ahasverus advena Waltl.)	0.005
8. Hairy fungus beetle (Typhaea stercorea L.)	0.002
9. Granary weevil (Sitophilus granarius L.)	0.001

* Note: Practically all of the rice weevils were found in 4 bins of high moisture wheat (see treatment 18, table 2).

** Note: The occurrence of the long-headed flour beetle is limited almost entirely to portions of grain in which large quantities of "flour" have been produced by lesser grain borer infestation.

Effect of Different Management Practices on Insect Populations in Wheat Stored in Ever-Normal Granary Type Bins

One of the major objectives in the wheat storage project has been to obtain an answer to the question "How long and under what conditions may wheat be stored safely?" Wheat has now been stored under different management practices, for more than two years, at the two experimental storage sites located at Jamestown, North Dakota and Hutchinson, Kansas. During this period, insect population levels at Jamestown have remained so low that no differentiations between different management practices is as yet discernible. At Hutchinson, however, great differences in insect population have been observed, which are attributable to differences in the treatment of the grain. The average intensity of insect infestation was determined for each group of bins receiving different treatments, and the results summarized in table 2. In evaluating the effectiveness of a given treatment, an infestation of one or more weevils, and/or five or more bran bugs per 1000 gram sample was considered a dangerous population. The date, October 1, was selected because it was felt that bins having low populations at that time would be unlikely to develop dangerous populations before the onset of winter conditions. It will be seen from the table that on this basis, two fumigations, one in August and the other in October, gives about complete protection from insect attack. Turning, cleaning and fumigating the grain gives practically as good protection, but is a much more expensive treatment. However, the long-time effect of turning grain on the rate of deterioration has not yet been determined, and it is possible that this method of handling may prolong the safe storage period beyond that afforded by other treatments.

Bins with white walls and roofs, constructed of either wood or steel, failed to develop dangerous populations during the season. Wood bins with red walls had much heavier infestation.

Bins which were fumigated in July developed threatening populations by October 1, having been exposed to re-infestation by migrating insects during August and September.

Bins receiving no treatment during the season had all developed serious infestations by October 1, and required fumigation to prevent deterioration. Treatments 13 to 16 in the table were in the same condition.

Treatment 17 includes those bins designated to receive one annual fumigation in October. It will be seen that by October 1 these bins were seriously infested. Several of them began to heat during September but were carried into October in order to determine the extent to which the infestation would develop. It is quite evident that this treatment is not practical, and in the future it is planned to fumigate these bins in September (see treatment 3, table 2).

Under treatment 18, table 2, a series of four bins equipped with wind pressure ventilators were filled early in July with 1943 crop wheat of a moisture content of 13.5%, with the object of testing the efficiency of such bins in drying high moisture grain. From the table it will be noted that these bins were the most heavily infested of any on the site. Moisture tests indicate that there has been but little loss of moisture so that weevils were strongly attracted to the grain, and were also able to increase rapidly.

Much of the grain in treatments 12 to 18 in table 2 required fumigation during October, to put it in condition for the winter. As a result, infestation was much less intense by the end of December than is indicated by the condition recorded on October 1.

Table 2: -- Comparison of insect infestation in wheat stored under different management practices, Hutchinson, Kansas. Condition as of October 1, 1943.

Treatment	No. bins	Infestation per 1000 grams		
		Bran bugs*	Weevils*	Total
1. Regular fumigation, August and October	11	0.1	0.	0.1
2. Turning, cleaning and fumigation when necessary	5	0.2	0.	0.2
3. Fumigation in September	17	0.6	0.2	0.8
4. Wood bins, white walls and roof	2	1.0	0.	1.0
5. Fumigation in August	21	1.8	0.5	2.3
6. Steel bins, white walls and roof	5	2.2	0.3	2.5
7. Steel bins, white walls and roof, grouped for shading	4	3.5	0.1	3.6
8. Wood bins, white walls only	9	3.4	0.6	4.0
9. Steel, insulation on grain surface, white walls	1	4.5	0.	4.5
10. Fumigation in July	17	5.2	0.9	6.1
11. Wood bins, red walls	2	6.0	1.5	7.5
12. No treatment during season, up to October 1	31	11.8	4.0	15.8
13. Turning in January	3	15.4	0.8	16.2
14. Steel, insulation on grain surface, unpainted walls	1	16.5	0.3	16.8
15. Oil spray on surface of grain, June and August	5	8.5	9.0	17.5
16. Turning and cleaning when necessary	5	8.3	9.7	18.0
17. Annual fumigation in October (before fumigation)	17	15.0	4.6	19.6
18. Wind pressure ventilation (high moisture wheat)	4	18.5	84.8	103.3

* Note: "Weevils" include the rice weevil, granary weevil and lesser grain borer; and "Bran bugs" include all other grain infesting species.

Further Observations on the Effect of Turning and Cleaning Wheat on Insect Populations

The effect of turning and cleaning grain on insect populations was discussed in a previous report. The subsequent development of insect populations was observed in four of the bins which were turned and cleaned early in September, as compared with the population trend in four bins of undisturbed grain. These data are presented in table 3. The outstanding difference between the turned grain and that which was left undisturbed was the tremendous increase in the number of the lesser grain borer in the turned grain. Turning had the effect of scattering the lesser grain borer population throughout the grain mass, and as the grain temperature was favorable for insect development at the time of turning, the result was a tremendous increase in borers throughout the grain. From these observations it is quite evident that turning and cleaning grain is of no value as a means of insect control, but rather, in the region where the lesser grain borer is present, such practices actually aggravate the situation. It may be noted here, that in order to control the infestation in the turned bins, it was necessary to use greatly increased dosages of fumigant.

Table 3: -- Rate of insect development in grain which has been turned and cleaned as compared with that in undisturbed grain at Hutchinson, Kansas.

Note: Samples consisted of 5-probe samples, amounting to about 5000 grams of wheat.

		Grain turned and cleaned Sept. 1, 1943 - 1000-bu. bins						
Bin No.	Species	Number per sample Aug. 1, 1943	Number before turning and cleaning Aug. 30, 1943	Number after turning and cleaning Sept. 2, 1943	Insects removed %	Number insects Oct. 1, 1943	Net change Aug.-Oct. %
2-15 to 1-14	Flat grain beetle	20	38	11	69	60	+300
	Sawtooth grain beetle	60	92	57	38	73	+122
	Red flour beetle	0	3	0	100	2	+200
	Lesser grain borer	2	18	35	-195	182	+9100
	Total	82	151	103	32	317	+390
1-14 to 1-15	Flat grain beetle	45	78	7	91	21	-53
	Sawtooth grain beetle	70	59	7	88	13	-81
	Lesser grain borer	2	8	1	87	17	+850
	Total	117	145	15	90	51	-56

(continued)

Table 3, continued

Bin No.	Species	Number per sample Aug. 1, 1943	Number before turning and cleaning Aug. 30, 1943	Number after turning and cleaning Sept. 2, 1943	Insects removed %	Number insects Oct. 1, 1943	Net change Aug.-Oct. %
		Undisturbed Grain					
3-10	Flat grain beetle	165				68	-59
	Sawtooth grain beetle	80				3	-96
	Lesser grain borer	5				13	+260
	Total	250				84	-66
3-11	Flat grain beetle	74				52	-30
	Sawtooth grain beetle	106				3	-97
	Red flour beetle	0				2	+200
	Lesser grain borer	0				13	+1300
	Total	180				70	-61

Grain turned and cleaned September, 1943 - 2740-bu. bins

Bin No.	Species	Number per sample before turning and cleaning Aug. 20, 1943	Number after turning & cleaning, Sept.	Insects removed %	Number insects Oct. 13, 1943	Net change Aug.-Oct. %
8-10 to 7-11	Flat grain beetle	30	12	60	18	-40
	Sawtooth grain beetle	260	75	71	21	-92
	Lesser grain borer	2	0	100	15	+750
	Total	292	87	70	54	-81
8-11 to 8-10	Flat grain beetle	30	8	73	7	-77
	Sawtooth grain beetle	10	2	80	1	-90
	Lesser grain borer	2	24	-1200	73	+3650
	Total	42	34	18	81	+194

Undisturbed grain

Bin No.	Species	Number per sample Aug 20, 1943	No. insects Sept. 29	No. insects Oct. 25	Net change Aug.-Oct. %
8-4	Flat grain beetle	40	56	36	-10
	Sawtooth grain beetle	170	354	153	-9
	Lesser grain borer	3	23	30	+1000
	Total	213	433	239	+115
8-5	Flat grain beetle	80	14		-82
	Sawtooth grain beetle	60	16		-73
	Lesser grain borer	1	1		0
	Total	141	31		-78

Fall Distribution of Insect Populations in Stored Wheat

As has been noted in previous preports, information is being obtained on the distribution of insect populations within the grain mass in wheat stored in various types of bins. During the October sampling at Hutchinson, the individual probe samples composing the average sample were examined separately in order to obtain further information on the distribution of the population under different densities of infestations. These data are presented in tables 4, 5, and 6. A total of 164 bins were sampled in this way, 19 of which were not infested and not included in the tables. In 1000-bushel bins, intensities of infestations ranged from zero to 336 insects per 1000-gram sample; in 2740-bushel bins the range was from zero to 430; in wood bins, from zero to 52.

In the smaller steel bins (1000 bushel) insects were most abundant in the south portion of the grain mass, while in 2740-bushel steel bins and in wood bins they were most numerous in the center. With few exceptions, the greatest intensity of infestation occurred in the upper half of the grain, although as the intensity increases there is a more general distribution of insects throughout the bin.

This information is of great value where large numbers of bins are to be sampled, since dangerous infestations are most likely to be discovered by sampling in the upper center and south portions of the bin, thus saving a large amount of labor.

Table 4: -- Intensity of infestation in individual probe samples composing the 5-probe average sample. 1000, 1250, 1500, and 2000 bushel steel bins. Hutchinson, Kansas, October, 1943.

Legend: * - 1250 bu. bins
** - 1500 bu. bins
*** - 2000 bu. bins
All others 1000 bu. bins

Bin No.	Location and number of insects per 1000-gram sample						
	Center	North	East	South	West	Total	Average
3-3	336	136	114	186	286	1058	211.6
3-1	90	98	152	92	166	598	119.6
2-2	58	50	58	57	116	339	67.8
1-14	70	56	69	71	51	317	63.4
1-9	26	8	12	194	24	264	52.8
12-12	44	44	20	117	11	236	47.2
1-12	20	12	10	101	5	148	29.6
12-11	21	10	14	48	51	144	28.8
4-10	2	11	2	90	35	140	28.0
3-10	15	2	16	49	2	84	16.8
3-16	4	16	6	28	26	80	16.0
3-17*	0	0	1	69	2	72	14.4
4-8	37	4	13	7	10	71	14.2
3-11	28	9	9	17	7	70	14.0
9-13	15	7	13	14	19	68	13.6
4-9	13	3	0	40	10	66	13.2
1-4	10	8	3	21	9	51	10.2
1-15	20	3	9	17	2	51	10.2
½-10	9	3	3	27	5	47	9.4
4-16	23	1	4	14	4	46	9.2
2-8	12	4	2	25	2	45	9.0
3-9	3	0	0	38	1	42	8.4
1-7	17	2	4	9	7	39	7.8
½-9	25	1	2	6	5	39	7.8
4-11	6	5	2	6	17	36	7.2
1-13	1	1	1	32	0	35	7.0
1-8	2	1	12	0	19	34	6.8
1-16	14	2	4	1	12	33	6.6
2-9	11	10	3	4	3	31	6.2
4-7	7	2	12	6	3	30	6.0
3-4	2	3	5	16	2	28	5.6
2-5	1	0	1	4	21	27	5.4
4-15*	1	0	0	22	0	23	4.6
2-16	3	0	17	2	0	22	4.4
4-13	6	0	3	8	2	19	3.8

(continued)

Table 4, continued

Bin No.	Location and number of insects per 1000-gram sample						
	Center	North	East	South	West	Total	Average
2-13	3	4	7	4	1	19	3.8
1-2	10	0	1	6	2	19	3.8
1-3	1	1	14	0	1	17	3.4
1-6	9	0	0	5	0	14	2.8
3-5	3	8	0	2	1	14	2.8
3-2	2	0	6	2	2	12	2.4
4-6	4	0	0	6	1	11	2.2
11-12	1	0	2	2	4	9	1.8
1-11	5	0	0	4	0	9	1.8
2-6	1	2	0	5	1	9	1.8
9-9**	7	1	0	0	0	8	1.6
2-4	2	2	0	1	3	8	1.6
3-7	4	0	1	2	1	8	1.6
3-8	5	0	2	0	0	7	1.4
2-14	0	0	6	1	0	7	1.4
½-2	0	1	0	5	0	6	1.2
2-12	3	0	0	2	0	5	1.0
½-7	1	0	1	1	2	5	1.0
10-8***	0	0	1	1	2	4	0.8
8-12	1	0	0	2	1	4	0.8
4-5	0	2	0	0	1	3	0.6
2-7	0	0	1	1	1	3	0.6
2-10	1	0	1	1	0	3	0.6
½-6	2	0	0	0	0	2	0.4
4-12	0	2	0	0	0	2	0.4
10-12	0	0	0	0	2	2	0.4
3-12	0	0	1	0	0	1	0.2
½-5	0	0	0	1	0	1	0.2
3-13	0	0	1	0	0	1	0.2
2-11	0	0	1	0	0	1	0.2
3-6	1	0	0	0	0	1	0.2
1-10	1	0	0	0	0	1	0.2
10-7***	0	0	0	0	1	1	0.2
Totals	1019	535	642	1492	962	4650	
Per cent of total:	21.9	11.5	13.8	32.1	20.7		

Table 5:--Intensity of infestation in individual probe samples composing the 10-probe average sample from 2740, 4000, and 5000 bushel steel bins, Hutchinson, Kansas, October, 1943.

Legend:--*=4000 bushel bins; **=5000 bushel bins; all others 2740 bushel bins.

Bin No.	Location and number of insects per 1000 grams														Ave. sample
	Center		North		East		South		West		Totals				
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower			
12-1	134	430	16	14	59	9	12	14	22	2	243	469	71.2		
9-6	169	158	56	4	85	16	41	3	61	7	412	188	60.0		
8-4	61	148	23	66	30	41	39	10	12	8	165	273	43.8		
7-1	150	17	9	1	2	1	184	4	2	1	347	24	37.1		
7-3	29	4	58	5	68	29	39	36	45	12	239	86	32.5		
6-4	8	0	0	0	1	0	130	60	5	0	144	60	20.4		
8-9	40	54	13	2	13	0	48	3	16	0	130	59	18.9		
5-1	56	48	16	3	11	0	3	0	29	2	115	53	16.8		
10-6	75	10	11	7	6	1	15	0	27	4	134	22	15.6		
5-5	93	4	1	1	21	8	19	5	2	0	136	18	15.4		
8-1	137	11	2	1	1	0	0	0	2	0	142	12	15.4		
6-2	37	2	24	13	12	1	18	25	19	1	110	42	15.2		
11-11	82	1	2	3	15	0	9	1	29	1	137	6	14.3		
6-8	66	6	5	0	5	1	20	14	17	4	113	25	13.8		
11-10	36	0	0	7	4	5	21	6	55	1	116	19	13.5		
6-1	8	0	14	1	10	0	91	3	2	2	125	6	13.1		
8-8	34	21	5	0	7	0	15	12	22	1	83	34	11.7		
6-7	32	0	2	1	36	0	23	1	5	0	98	2	10.0		
5-2	24	11	20	3	20	0	3	8	9	0	76	22	9.8		
11-3	32	1	3	10	7	0	23	5	7	0	72	16	8.8		
5-10**	8	1	4	3	20	2	21	8	8	9	61	23	8.4		
8-10	8	0	12	1	10	3	21	2	19	5	70	11	8.1		
11-2	20	12	5	3	5	2	10	6	12	2	52	25	7.7		
5-11*	8	7	3	4	10	9	11	5	11	3	43	28	7.1		
12-10	32	4	3	0	2	2	10	4	8	0	55	10	6.5		
10-10	3	0	4	0	3	5	20	11	10	8	40	24	6.4		
7-11	7	13	6	10	1	4	7	4	3	4	24	35	5.9		
6-12**	0	0	0	0	0	0	6	52	0	0	6	52	5.8		
7-7	2	4	6	0	4	3	6	11	18	3	36	21	5.7		
8-6	13	18	2	5	3	2	3	0	8	0	29	25	5.4		
12-2	7	0	0	1	1	3	15	4	12	9	35	17	5.2		
6-5	11	3	1	0	1	2	14	5	6	7	33	17	5.0		
5-6	5	0	0	0	22	2	17	2	0	0	44	4	4.8		
7-10	9	1	0	0	0	0	33	2	2	0	44	3	4.7		
5-4	18	3	1	3	9	0	8	0	1	0	37	6	4.3		
8-5	10	0	3	0	9	2	4	1	5	1	32	4	3.6		
5-9	5	14	2	4	2	1	4	0	2	2	15	21	3.6		
7-4	2	1	4	5	4	2	6	9	1	1	17	18	3.5		

(continued)

Table 5, continued.

Bin No.	Location and number of insects per 1000 grams												Ave. sample
	Center		North		East		South		West		Totals		
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	
8-2	3	6	4	1	0	1	9	3	5	2	21	13	3.4
10-9	2	0	2	0	5	0	7	1	9	2	25	3	2.8
12-8	0	0	0	1	4	0	1	0	7	12	12	13	2.5
11-9	1	0	3	1	6	0	12	0	1	0	23	1	2.4
5-3	0	0	6	5	2	0	1	9	0	1	9	15	2.4
6-13*	4	0	1	2	3	0	1	12	0	0	9	14	2.3
8-3	1	4	3	0	0	3	1	1	3	5	8	13	2.1
7-5	12	1	1	0	1	0	3	0	0	0	17	1	1.8
6-3	3	0	6	0	3	0	0	1	3	0	15	1	1.6
6-6	4	0	1	0	7	1	0	0	1	0	13	1	1.4
8-7	0	1	0	0	0	1	4	0	5	1	9	3	1.2
11-7	3	0	1	0	0	1	2	2	1	0	7	3	1.0
11-4	1	0	0	0	0	0	5	2	1	0	7	2	0.9
12-7	1	4	0	0	0	1	1	1	0	0	2	6	0.8
7-8	0	0	0	0	3	1	0	1	2	0	5	2	0.7
12-3	1	0	0	0	0	0	6	0	0	0	7	0	0.7
9-12	0	0	4	0	0	0	1	0	0	1	5	1	0.6
9-11	1	0	1	0	0	0	2	0	0	0	4	0	0.4
7-2	3	0	0	0	0	0	0	0	0	0	3	0	0.3
11-5	0	0	0	0	0	0	3	0	0	0	3	0	0.3
7-9	1	1	0	0	0	0	0	0	1	0	2	1	0.3
12-9	0	0	0	0	1	0	2	0	0	0	3	0	0.3
9-4	1	0	0	0	0	0	0	0	1	0	2	0	0.2
9-7	0	0	0	0	0	0	2	0	0	0	2	0	0.2
5-8	0	2	0	0	0	0	0	0	0	0	0	2	0.2
9-10	1	0	0	0	0	0	1	0	0	0	2	0	0.2
10-2	0	0	0	0	0	0	1	0	0	0	1	0	0.1
11-6	0	0	1	0	0	0	0	0	0	0	1	0	0.1
Totals:	1514	1026	370	191	554	165	1034	369	554	124	4026	1875	
Percent of total:	25.7	17.4	6.3	3.2	9.4	2.8	17.5	6.3	9.4	2.1	68.2	31.8	

Table 6:--Intensity of infestation in individual probe samples composing the 6-probe average sample, 1500-bushel wood bins, Hutchinson, Kansas, October, 1943.

A. Bins oriented long axis north-south

Bin No.	Locations and numbers of insects per 1000 grams								Ave. per 1000 grams
	North		Center		South		Total		
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	
13-7	10	2	52	4	4	0	66	6	12.0
13-10	19	0	30	8	12	2	61	10	11.8
13-3	0	0	52	8	2	0	54	8	10.3
13-2	4	0	14	0	4	4	22	4	4.3
13-8	2	4	4	8	2	0	8	12	4.2
13-11	6	0	8	4	2	0	16	4	3.3
13-1	0	0	12	1	4	0	16	1	2.9
13-9	0	0	2	4	2	0	4	4	1.3
13-4	4	0	0	0	2	0	6	0	1.0
13-6	0	0	4	0	0	0	4	0	0.7
Totals	45	6	178	37	34	6	257	49	
Per cent of total	14.7	2.0	58.1	12.1	11.1	2.0	84.0	16.0	

B. Bins oriented long axis east-west

Bin No.	Location and numbers of insects per 1000 grams								Ave. per 1000 grams
	East		Center		West		Total		
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	
336	6	0	17	13	1	0	24	13	6.2
337	0	0	1	18	6	0	7	18	4.2
Totals	6	0	18	31	7	0	31	31	
Per cent of total	9.7	0	29.1	50.0	11.2	0	50.0	50.0	

Study of the Migration of Stored Grain Insects by Means of Traps

During the past season at Hutchinson, three types of insect traps were employed in a study of the migration of stored grain insects to the site and into the bins. The traps consisted of (1) tanglefoot screens placed along the boundaries of the site, (2) ventilator traps in two bins, and (3) a revolving trap located near the center of the site.

Tanglefoot Boundary Traps

Four screens, each 3 feet square, were mounted on 2" x 4" supports and were elevated 4 feet above the ground level. One screen was erected at the mid-point of each boundary of the bin site. Manila wrapping paper was fastened on each screen, and the paper was then coated with tanglefoot. At weekly intervals, beginning the first week in June, the paper was removed, the catch of stored grain insects was recorded, and a new square of paper coated with tanglefoot was mounted on each screen.

The record of the catch for each period is given in table 7. From the table it may be noted that nearly 3/5 of the insects were taken from the screen located on the north side of the site. There was a considerable amount of variation in the catch for the different screens, and also between the different periods. It should be noted that nearly 70 percent of the insects were taken between July 1st and August 31st, with the peak of migration being recorded during August.

During the four months of operation a total of 3710 stored grain insects were caught, representing six species. These species, together with the numbers taken at the four locations are listed in table 8. It may be noted that of the six species represented, the flat grain beetle comprised nearly 93 percent of the total number of insects recorded. The lesser grain borer, a stored grain pest of major importance in the region, ranked second in abundance.

Table 7:--Seasonal flight of stored grain insects as indicated by numbers captured on tanglefoot screens, Hutchinson, Kansas, 1943.

	Location of traps and numbers of insect caught					
Period	North	East	South	West	Total	Percent of total catch
1943						
June 1-7	84	14	7	11	116	3.1
8-15	166	22	3	71	262	7.1
16-22	37	32	12	17	98	2.6
23-29	8	3	6	11	28	0.8
June 30-July 6	14	48	25	17	104	2.8
July 7-13	11	35	41	107	194	5.2
14-20	335	41	4	38	418	11.3
21-27	86	Not operated	Not operated	57	143	3.9
July 28-Aug.3	145	46	14	38	243	6.5
Aug. 4-10	169	47	114	180	510	13.7
11-24	298	54	3	142	497	13.4
25-31	314	68	63	39	484	13.0
Sept.1-7	23	Not operated	Not operated	66	89	2.4
10-20	388	18	0	19	425	11.5
21-27	77	5	0	17	99	2.7
Totals	2155	433	292	830	3710	
Percent of total	58.1	11.7	7.9	22.4		

Table 8:--Comparative abundance of the species of stored grain insects trapped on tanglefoot screens, Hutchinson, Kansas, 1943.

Species	Location and number of insects					
	North	East	South	West	Total	% of total
Flat grain beetle	2006	404	239	788	3437	92.6
Lesser grain borer	129	18	44	37	228	6.2
Hairy fungus beetle	10	2	3	1	16	0.4
Rice weevil	6	5	0	1	12	0.3
Red flour beetle	3	4	2	1	10	0.3
Foreign grain beetle	1	0	4	2	7	0.2
Totals	2155	433	292	830	3710	
Percent of total	58.1	11.7	7.9	22.4		

Ventilator traps

At the Hutchinson site two bins, which have been tightly caulked so that the only means by which insects can gain entrance is through the roof ventilator, have been fitted with ventilator traps to retain any insects entering in this manner. These traps were operated continuously from May 25 to November 3, 1943. The traps were examined at approximately weekly intervals throughout the season, and the number and species of insects was recorded. The results are given in table 9. It should be noted that the larger number of insects were taken in the trap which was located in the bin containing 12% moisture grain. As in the case of the tanglefoot screens, the greatest numbers of insects were taken during August.

During the season, a total of 1358 specimens of stored grain insects were taken in the ventilator traps, representing seven species. These are listed in table 10 together with the numbers taken in each of the traps. The flat grain beetle comprised about 90 percent of the catch, with the lesser grain borer ranking second in abundance.

Table 9:--Number of insects entering ventilator traps in bins at Hutchinson, Kansas, 1943.

Period	Bin No. 10-12 11.5% moisture wheat		Bin No. 1-1 12.0% moisture wheat		Total insects 2 traps	Percent of total
	No. insects	% of total	No. insects	% of total		
May 25-31	5	0.9	1	0.1	6	0.4
June 1-7	2	0.3	17	2.2	19	1.4
8-15	14	2.4	19	2.4	33	2.4
16-22	10	1.7	8	1.0	18	1.3
23-29	9	1.6	40	5.1	49	3.6
June 30-July 6	14	2.4	25	3.2	39	2.9
July 7-13	7	1.2	17	2.2	24	1.8
14-20	18	3.1	26	3.3	44	3.2
21-27	49	8.5	24	3.1	73	5.4
July 28-Aug. 3	74	12.8	35	4.5	109	8.0
Aug. 4-10	81	14.0	120	15.4	201	14.8
11-24	77	13.3	206	26.4	283	20.8
25-31	67	11.6	154	19.7	221	16.3
Sept.1-7	33	5.7	46	5.9	79	5.8
8-14	79	13.7	27	3.5	106	7.8
15-21	9	1.6	6	0.8	15	1.1
22-28	7	1.2	3	0.4	10	0.7
Sept.29-Oct. 5	0	0	0	0	0	0
Oct. 6-12	13	2.3	4	0.5	17	1.3
13-20	2	0.3	1	0.1	3	0.2
Oct.21-Nov. 3	7	1.2	2	0.3	9	0.7
Totals	577		781		1358	
Percent of total		42.5		57.5		

Table 10:--Comparative abundance of the species of stored grain insects taken in ventilator traps, Hutchinson, Kansas, 1943.

Species	Total catch			Percent of catch		
	Bin 10-12	Bin 1-1	Total	Bin 10-12	Bin 1-1	Total
Flat grain beetle	533	685	1218	92.4	87.7	89.7
Lesser grain borer	18	38	56	3.1	4.9	4.1
Sawtooth grain beetle	2	38	40	0.3	4.9	2.9
Foreign grain beetle	10	14	24	1.7	1.8	1.8
Red flour beetle	6	2	8	1.0	0.3	0.6
Rice weevil	1	4	5	0.2	0.5	0.4
Hairy fungus beetle	7	0	7	1.2	0	0.5
Totals	577	781	1358	42.5	57.5	

Revolving Insect Trap

This trap consists of two nets revolving on six-foot arms, powered by an electric motor. The nets revolve at the rate of approximately 50 R.P.M. One net runs 2 feet above the ground level, and the other, 6 feet above the ground. The daytime catches were for the period 8:00 A. M. to 5 P. M., and the nighttime catches from 5:00 P.M. to 8:00 A.M. During the past season the trap was run at frequent intervals and observations were made on both the daytime and nighttime flights. Owing to the pressure of other work, it was not practicable to operate the trap continuously. The results are given in table 11.

It may be noted from the table that (1) the greatest flight occurred between 5:00 P.M. and 8:00 A.M. during the warmer part of the summer; (2) about equal numbers of insects were caught in each net; (3) the greatest numbers were taken during August and September.

A total of nearly 15,000 stored grain insects were taken in the revolving trap during the season, representing 7 species. These species together with the numbers taken are listed in table 12. As in the case of the tanglefoot screens and the ventilator traps, the flat grain beetle was taken in greatest abundance.

In summing up the work with traps, it is quite evident that (1) migrating insects are an important source of infestation of grain stored in bins of the type used on this project; (2) although some migration of stored grain insects occurs throughout the summer months, the most critical period is during August and early in September. It is during this period that the rate of re-infestation of grain is much more rapid than at other times of the year, and at times may be rapid enough to nullify fumigation. For this reason, it is necessary that fumigation be delayed, if possible, until near the end of the migration period, but applied before the development of dangerous populations.

Table 11:--Number of stored grain insects caught in revolving trap, Hutchinson, Kansas, 1943.

Date	Daytime run--8 A.M. to 5 P.M.				Nighttime run--5 P.M. to 8 A.M.			
	Number of insects			Percent of total catch	Number of insects			Percent of total catch
	Upper net	Lower net	Total		Upper net	Lower net	Total	
1943								
May 26(1)	22	25	47	8.45	Not operated			
27(2)	18	31	49	8.81	37	41	78	0.54
June 1	1	0	1	0.18	75	223	298	2.06
7	Not operated				80	135	215	1.49
11	0	0	0	0	1	1	2	0.02
16	1	0	1	0.18	50	37	87	0.60
21	Not operated				344	450	794	5.50
25	0	0	0	0	44	38	82	0.57
29	0	0	0	0	1	0	1	0.01
July 2	0	0	0	0	Sack burst	6	6	0.04
5	Not operated				633	522	1155	8.00
7	2	0	2	0.36	Not operated			
9	Not operated				200	258	458	3.17
10	0	0	0	0	Not operated			
13(3)	0	0	0	0	309	365	674	4.67
16(3)	2	1	3	0.54	56	14	70	.48
20	17	0	17	3.06	128	Sack burst	128	.89
26	15	0	15	2.70	224	245	469	3.23
Aug. 2	0	0	0	0	73	120	193	1.33
9	1	2	3	0.54	242	333	575	3.98
12	0	0	0	0	62	103	165	1.14
20	Not operated				1163	1297	2460	17.03
21	1	14	15	2.70	Not operated			
24	0	0	0	0	227	251	478	3.31
Sept.1	56	85	141	25.36	1427	1074	2501	17.32
3	Not operated				145	120	265	1.84
4	59	59	118	21.22	Not operated			
6	Not operated				65	87	152	1.05
7	15	24	39	7.01	Not operated			
10	Not operated				1454	1326	2780	19.25
13	Not operated				128	102	230	1.59
14	5	2	7	1.26	Not operated			
16	Not operated				1	3	4	0.03
17	1	0	1	0.18	Not operated			
20	Not operated				9	1	10	0.07
21	1	1	2	0.36	Not operated			
24	Not operated				72	38	110	0.76
Oct. 6	Not operated				0	0	0	0
7	41	54	95	17.09	Not operated			
Totals	258	298	556		7250	7190	14440	

(1) Trap operated from 2 to 5 P.M.
(2) Trap operated from 1 to 5 P.M.
(3) Rainy

Table 12:--Comparative abundance of the species of stored grain insects caught in revolving trap, Hutchinson, Kansas, 1943.

Species	Total catch				Total catch			Percent caught		
	Day		Night							
	Upper	Lower	Upper	Lower	Day	Night	D & N	Day	Night	Total
Flat grain beetle	194	240	4351	4837	434	9188	9622	78.3	63.	64.16
Hairy fungus beetle	1	2	1633	1195	3	2828	2831	0.4	19.2	18.87
Foreign grain beetle	7	8	1144	1087	13	2231	2244	2.3	15.5	14.96
Lesser grain borer	53	48	113	59	101	172	273	18.3	1.2	1.82
Red flour beetle	1	2	5	9	3	12	15	0.4	0.08	0.10
Long-headed flour beetle	0	0	3	2	0	5	5	0.	0.03	0.03
Rice weevil	2	0	3	1	2	4	6	0.3	0.03	0.04
Totals	258	298	7250	7190	556	14440	14996	3.7	96.3	

Effect of Insect Infestation on Temperature and Moisture Conditions in Grain Stored in Steel Bins

As insect infestation increases in intensity in stored grain, there is an accompanying rise in the grain temperatures. These areas of high temperature coincide with the areas of heavy infestation. Observations have been made from time to time in grain owned by the Commodity Credit Corporation to determine the temperature-moisture-insect relationships. During November such a study was conducted in a 2000 bushel lot of wheat stored in a steel bin at Chase, Kansas. At the time of inspection, the surface grain over the infested portion had become caked because of accumulation of moisture. Temperatures were taken in various parts of the grain, and samples drawn for the determination of insect infestation and moisture content of the grain. The results are shown graphically in figures 1 and 2. The points of equal temperature are connected by lines, and the grain moisture and insect infestation in different portions of the grain are indicated by the figures.

It will be noted that the greatest intensity of infestation occurred just outside the region of highest temperature, which was located near the south wall, in the upper portion of the grain. The moisture gradient over the hot spot is typical for bins in this condition. The temperatures in an uninfested bin are shown in figure 3.

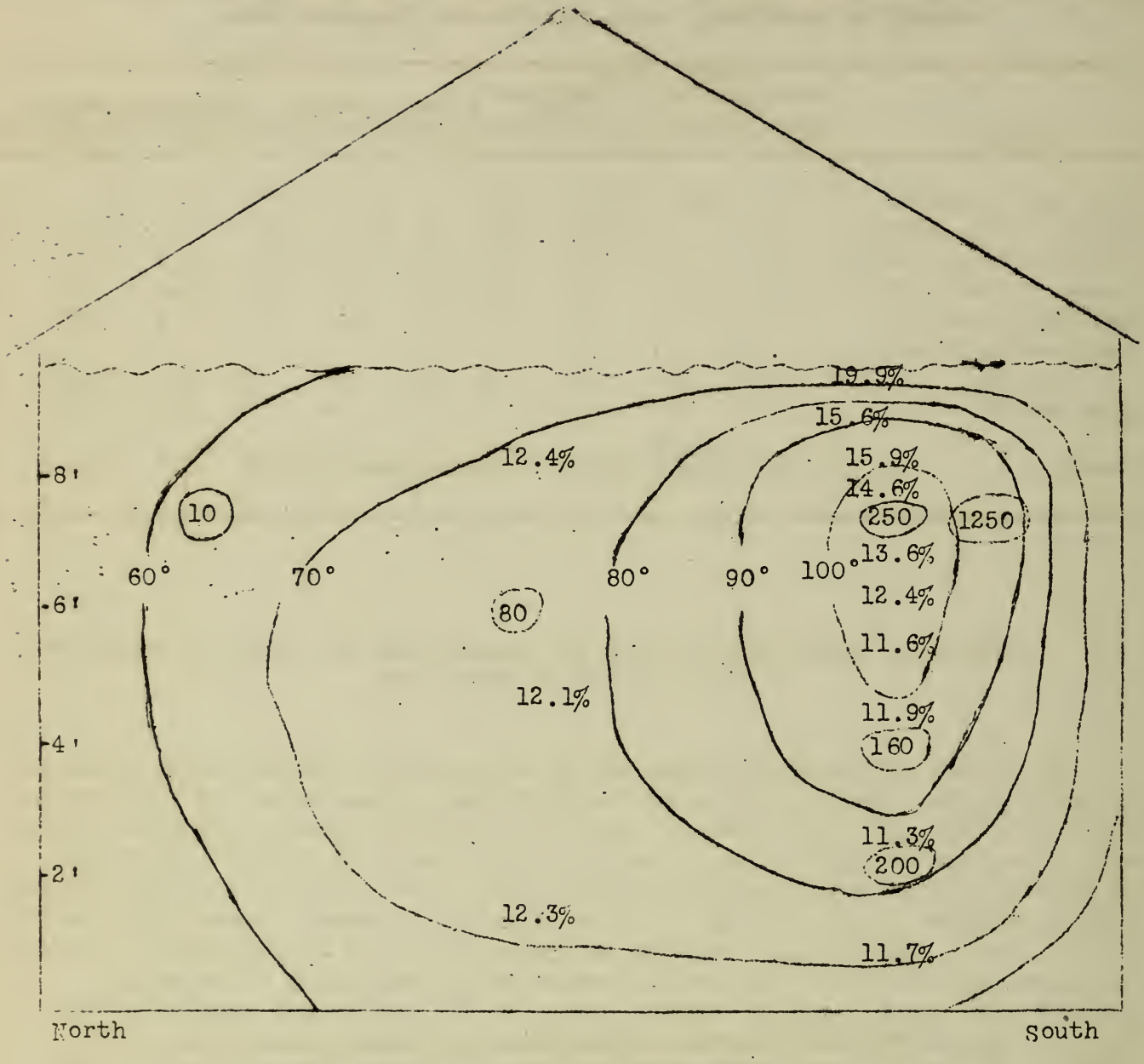


Fig. 1:--Temperature and moisture condtions in relation to insect infestation in wheat stored in a 2000-bu. steel bin, Chase, Kansas, November, 1943.

Legend: Figures inside circles -- Number of insects per 1000 grams. Isothermal lines in 10° intervals. Degrees F. Moisture gradients in percent -- %.

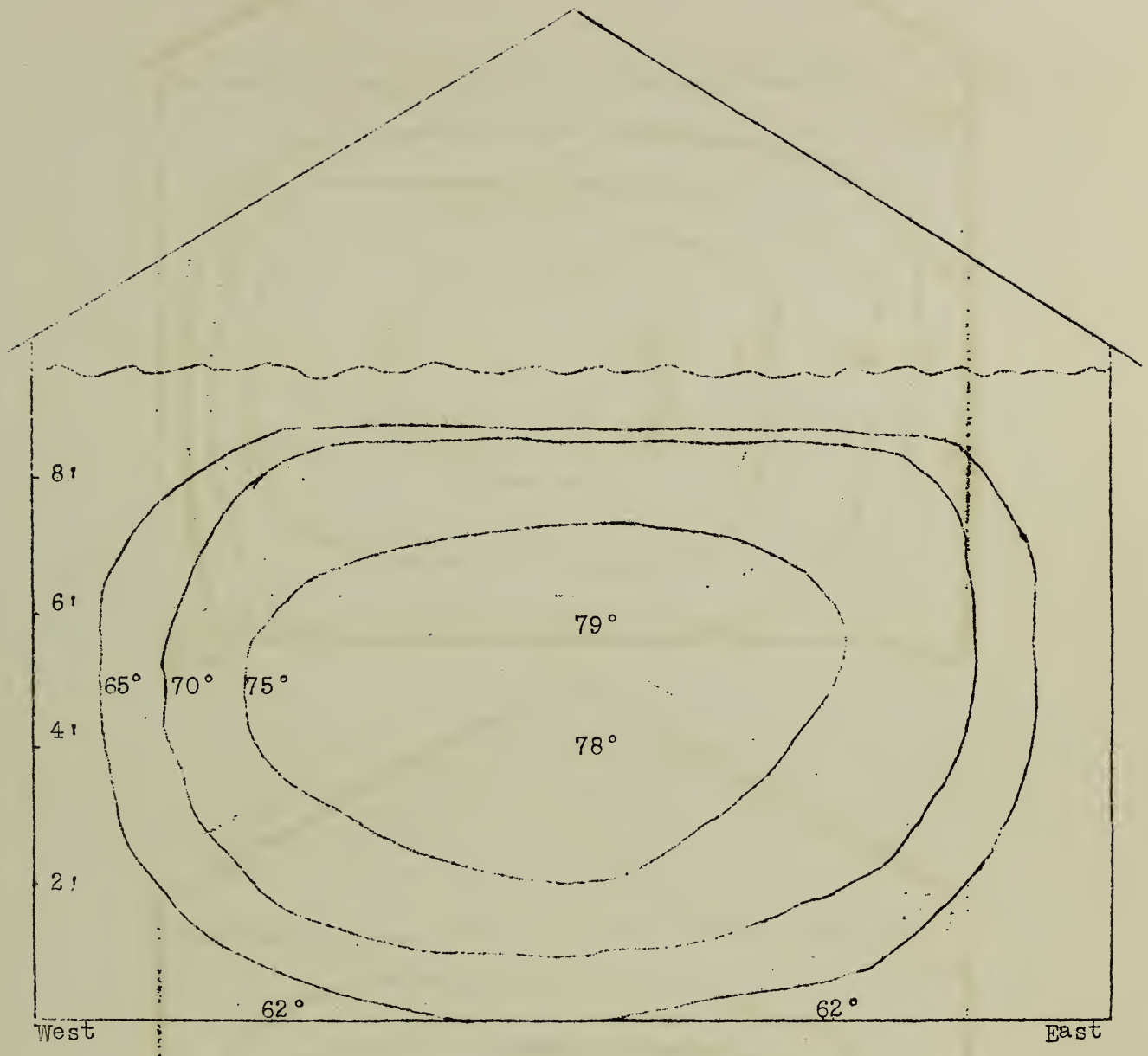
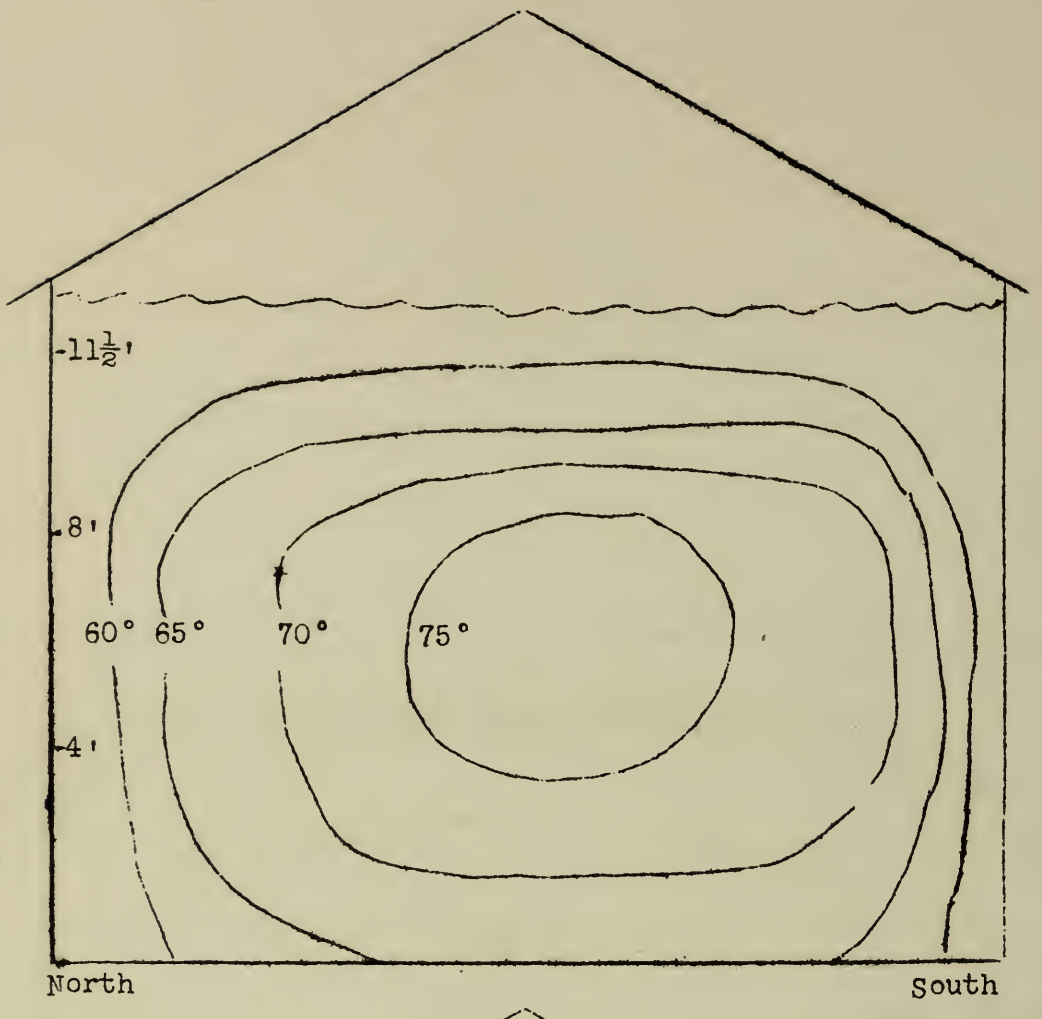


Fig. 2.--Isotherms in a 2000-bu. steel bin, Chase, Kansas, November, 1943.



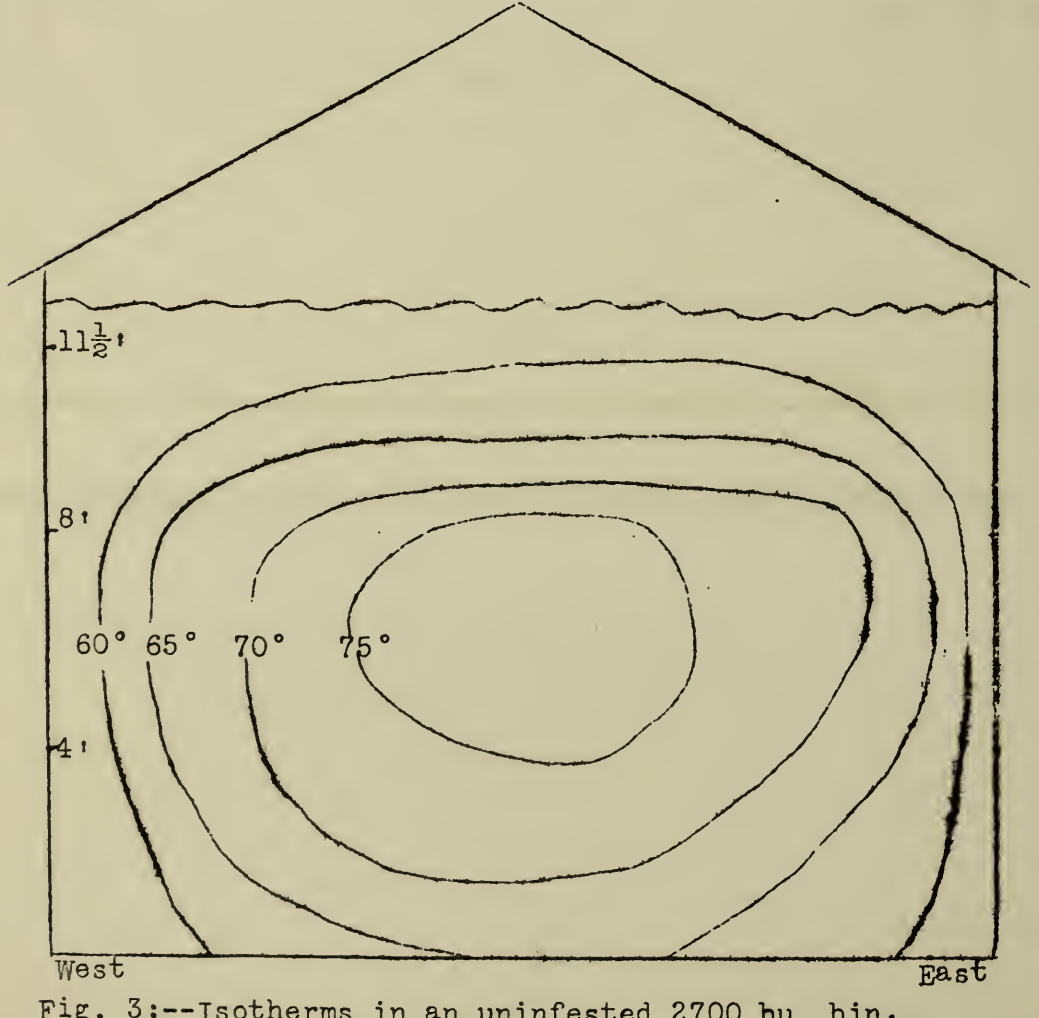


Fig. 3:--Isotherms in an uninfested 2700 bu. bin, Hutchinson, Kansas, November, 1943.

Further Work on the Reliability of Sampling Technique

In a previous report the reliability of the sampling technique was discussed as applied to lightly infested bins. Estimates of the insect populations in the bins located at the Jamestown and Hutchinson wheat storage sites are based on the infestation in "average" sample. These average or composite samples are drawn from ten places in the 2740-bu. bins, and five places in 1000-bu. bins, representing grain from the center, north, east, south, and west portions of the grain mass. The insect infestation is thus determined in 5 or 10 places in the bin. The average infestation for the bin is derived by averaging the 5 or 10 sub-samples comprising the composite sample.

During October, 25 average samples were drawn from a heavily infested bin at Hutchinson to determine the variation between samples under conditions of heavy infestation. The results are tabulated in table 13. The greatest concentration of insects (50%) was found in the south portion of the bin, while those in the center ranked second (25%). Thus, even in a heavily infested bin, three fourths of the insects were in the center and south portions of the grain. With regard to the vertical distribution, 64 percent were found in the upper half of the bin, 34 percent being in the upper south portion.

The numbers of insects found in the twenty five average samples varied 10.1 to 26.7, the mean being 18.2 $\pm$ 0.912. From these results, it appears that the present method of sampling may be expected to give a fairly reliable estimate of the insect infestation. However, this study serves also to emphasize the importance of determining the infestation in each of the sub-samples, in order to locate centers of dangerous populations. For practical purposes, it is now believed that sampling only in the upper half of the center and south portions of the grain will, in most cases, reveal any dangerous infestations. Where large numbers of bins, such as those owned by the Commodity Credit Corporation, require sampling, the above method of detecting insect infestation would save much of the cost of labor.

Table 13:--Variation in insect infestation in average samples taken from bin 8-4, Hutchinson, Kansas, October, 1943.

Sample number	Total number insects per probe sample										Average per 1000 grams
	Center		North		East		South		West		
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	
1	38	18	8	6	42	2	60	23	5	8	21.0
2	21	8	5	5	11	1	117	14	0	0	18.2
3	35	35	9	7	31	1	80	29	12	6	24.5
4	24	23	5	3	31	2	64	16	5	1	17.4
5	29	14	10	13	24	5	117	33	5	4	25.4
6	30	7	10	2	12	1	15	46	12	4	13.9
7	48	23	14	27	12	2	90	27	4	1	24.8
8	21	7	4	3	20	1	44	18	5	3	12.6
9	32	13	3	5	30	16	45	30	5	22	20.1
10	37	11	5	4	19	4	77	41	1	3	20.2
11	8	10	11	4	32	13	87	48	2	8	22.3
12	9	16	5	3	9	0	29	44	12	2	12.9
13	15	22	7	2	13	3	17	11	9	2	10.1
14	22	15	2	2	13	1	41	53	7	0	15.6
15	18	19	5	7	41	6	155	12	2	2	26.7
16	14	18	9	5	18	5	66	28	7	2	17.2
17	17	46	10	3	20	11	52	2	2	3	16.6
18	19	24	6	4	8	2	62	62	5	3	19.5
19	28	38	10	3	14	21	67	22	2	4	20.9
20	24	36	2	4	11	6	92	32	2	3	21.2
21	11	32	5	4	14	6	27	10	2	2	11.3
22	12	33	5	0	22	1	38	32	8	2	15.3
23	11	48	6	20	10	5	10	10	4	5	12.9
24	16	25	4	2	16	9	44	24	2	2	14.4
25	17	50	10	5	19	2	69	31	4	5	21.2
Totals	556	591	170	143	492	126	1565	698	124	97	
Per cent of total	12.2	13.0	3.7	3.1	10.8	2.8	34.3	15.3	2.7	2.1	
Means	22.2	23.6	6.8	5.7	19.7	5.0	62.6	27.9	5.0	3.9	18.2
Standard Deviation:	4.56										
True Mean:	18.2 ± .912										

	Upper Half	Lower Half	Total
Total No. insects	2907	1655	4562
Per cent of total	63.7	36.3	

Experimental Fumigation of Stored Wheat

Tests with various fumigants have been conducted during the quarter at Hutchinson, Kansas. These materials included carbon tetrachloride, ethylene dichloride, propylene dichloride, and various mixtures of carbon tetrachloride with ethide, ethylene dichloride, chloropicrin, carbon disulphide, acrylonitrile, trichloroacetonitrile, B-methylallyl chloride, and methyl bromide. Observations were made on the efficiency of these fumigants on both the egg and adult stages in check-probes, and also on the native populations within the bins. The results are summarized in tables 14 and 15.

Carbon tetrachloride alone gave good kills in both the check-probes and in the native populations, when used at a dosage of 3 gals. per 1000 bushels. Many of these bins contained much "flour" milled by heavy infestations of the lesser grain borer. In previous tests a dosage of 5 to 6 gals. per 1000 bushels of the 3-1 mixture of ethylene dichloride - carbon tetrachloride has been required to bring similar infestations under control.

In one bin which was fumigated immediately after turning and cleaning, carbon tetrachloride at a dosage of 1 gallon per 1000 bushels gave perfect results.

The mixture of carbon disulphide (20%) and carbon tetrachloride (80%) gave good results with adults, but failed to perform as well with eggs.

A mixture of chloropicrin (2 lbs.) with enough carbon tetrachloride to make 1 gallon applied at a dosage of 1.5 gallons of the mixture per 1000 bushels gave perfect kills with eggs and adults.

Dowfume Br-10 (3-1 mixture ethylene dichloride - carbon tetrachloride plus 10% methyl bromide) also gave perfect kills of both eggs and adults in check-probes, but failed with the native population.

The mixture of 2 lbs. of Ethide in enough carbon tetrachloride to make 1 gallon applied at the rate of 1.5 gals. of the mixture per 1000 bushels gave unsatisfactory results at this dosage. In laboratory tests Ethide has been given a high toxicity rating.

Tests with a mixture of 1 part each of acrylonitrile and trichloroacetonitrile, and 18 parts of carbon tetrachloride gave erratic results in 2740-bushel bins when applied at a dosage of 1 gallon of the mixture per 1000 bushels, indicating that a dosage of 1.5 to 2 gallons of the mixture will be required in bins of this capacity. In 1000-bushel bins a dosage of 2 gallons of the mixture per 1000 bushels gave consistently good results with both eggs and adults in check-probes, and in the native population.

The results obtained from the use of ethylene dichloride alone indicate that it is considerably less toxic than carbon tetrachloride alone.

Propylene dichloride is less toxic than ethylene dichloride to both eggs and adults.

Tests with various mixtures of B-methylallyl chloride with carbon tetrachloride indicate that a mixture composed of 20% B-methylallyl chloride with 80% carbon tetrachloride applied at a dosage of 1.5 gallons of the mixture per 1000 bushels in 2740-bushel bins, and 2 gallons per 1000 bushels in 1000-bushel bins can be expected to give good kills. A 1-4 mixture was highly toxic to the eggs.

Further tests with the 3-1 mixture of ethylene dichloride - carbon tetrachloride confirmed previously established dosages of 4 gallons per 1000 bushels in undisturbed grain. In grain recently turned and cleaned, a dosage of 2 gallons per 1000 bushels gave a good kill in both check-probes and native population.

In considering the results with the various mixtures used in these tests it should be borne in mind that carbon tetrachloride has proved to be a very toxic material for grain fumigation. Therefore, when mixed with other toxic materials it is frequently difficult to determine the degree to which the carbon tetrachloride affects the results.

While an attempt was made to reduce the amount of carbon tetrachloride in the several mixtures, the mechanics of the application of the fumigant require a minimum bulk of about 1.5 gallons per 1000 bushels in order to insure an even distribution on the grain.

The tests with carbon tetrachloride were made under as severe conditions of infestation as could be found among the bins on the Hutchinson site. The grain in some of the bins contained large amounts of the "flour" produced by lesser grain borer infestations. Successful fumigation under these conditions is difficult, yet carbon tetrachloride gave excellent results.

As a result of the work with carbon tetrachloride during the past season, it is felt that this material can be recommended for use as a fumigant in grain stored in steel bins.

Table 14:--Results of the experimental fumigation of wheat stored in steel and wood bins, October-December, 1943, Hutchinson, Kansas

Fumigant	Bin No.	Capacity (bu.)	Dosage per 1000 bu. (gals.)	Mortality: Probes	Mortality: Natural population	Remarks
Carbon tetrachloride	12-7	2740	1	100	100	After turning & cleaning grain
	10-10	2740	1	85	0	
	4-8	1000	1.5	94	94	
	4-9	1000	2	100	78	
	8-12	1000	2	100	94	
	10-12	1000	2	100	96	
	12-11	1000	2		48	)Much "flour" on account of
	12-12	1000	2		64	)lesser grain borer
	4-15	1000	2		85	
	5-4	2740	2		76	
	5-5	2740	2		94	
	5-6	2740	2		0	)"Floury" lesser grain borer
	6-3	2740	2		75	
	6-4	2740	2		89	
	6-7	2740	2		49	)Much "flour" on account of
	6-8	2740	2		48	)heavy lesser grain borer
	7-3	2740	2		82	)infestation
	7-4	2740	2		77	
	9-6	2740	2		91	
	10-5	2740	2		100	
	11-2	2740	2		77	
	12-1	2740	2		96	
	12-2	2740	2		79	
	5-11	4000	2		87	
	2-8	1000	3	100	98	
	2-9	1000	3	100	74	
	12-11	1000	3		97	)Much "flour"
	12-12	1000	3		78	)on account of
	5-6	2740	3		80	)lesser grain borer
	6-4	2740	3		100	
	6-7	2740	3		98	)Much "flour" on account of
	6-8	2740	3		81	)lesser grain borer
	7-3	2740	3		100	
	9-6	2740	3		80	
Carbon disulphide 20%-Carbon tetrachloride 80%	3-8	1000	3	100	100	
	3-9	1000	3	100	100	
Chloropicrin 2# in carbon tetrachloride to make 1 gallon	1-16	1000	1.5	100	100	
	2-16	1000	1.5	100	95	
Dowfume Br-10(3-1 mix.: ethylene dichloride--carbon tetrachloride +10% methyl bromide)	2-13	1000	2	100	47	
	9-13	1000	2	100	72	

(continued)

Table 14, continued

Fumigant	Bin No.	Capacity (bu.)	Dosage per 1000 bu. (gals.)	Mortality: Probes	Mortality: Natural population	Remarks
Ethide 2# in carbon tetrachloride to make 1 gallon	2-6	1000	1.5	96	67	
	2-7	1000	1.5	100	50	
Acrylo-trichloro-acetonitrile mixture (1 part acrylonitrile (1 part trichloroacetonitrile (18 parts carbon tetrachloride	1-13	1000	1	98.7	80	
	3-5	1000	1	82.5	79	
	7-1	2740	1	90	97	
	8-1	2740	1	100	98	
	10-9	2740	1	100	100	
	5-10	5000	1	78	78	(Much "flour" on account
	6-12	5000	1	100	40	(of lesser grain borer
	1-12	1000	1.5	100	95	
	4-6	1000	1.5	99	82	
	10-6	2740	1.5	100	97	
	1-8	1000	2	99	94	
	1-9	1000	2	100	95	
	3-4	1000	2	100	85	
	4-7	1000	2	99	97	
	11-4	2740	2	100	0	Floury: Lesser grain borer
Ethylene dichloride	2-4	1000	4	94	100	
	2-5	1000	4	82	100	
	8-2	2740	4	100	88	
	8-3	2740	4	100	100	
	336	1500	6	93	100	Wood bin
Propylene dichloride	3-6	1000	4	38	100	
	3-7	1000	4	63	75	
	7-7	2740	4	100	91	
	8-6	2740	4	100	95	
	337	1500	6	68	100	Wood bin
B-methylallyl chloride 16% carbon tetrachloride 84%	1-4	1000	1.5	73	85	
	1-14	1000	1.5	90	70	
B-methylallyl chloride 20% carbon tetrachloride 80%	11-10	2740	1.5	100	100	)Much "flour"
	11-11	2740	1.5	100	99	)on account of
	12-10	2740	1.5	100	100	)lesser grain borer
B-methylallyl chloride 25% carbon tetrachloride 75%	1-6	1000	1.5	98	93	
	1-7	1000	1.5	100	44	

(continued)

Table 14, continued

Fumigant	Bin No.	Capacity (bu.)	Dosage per 1000bu. (gals.)	Mortality: Probes	Mortality: Natural population	Remarks
B-methylallyl chloride 67% carbon tetrachloride 33%	4-10	1000	1.5	86	81	)Much "flour" on account
	4-11	1000	1.5	89	91	)of lesser grain borer
Ethylene dichloride 75% carbon tetrachloride 25%	3-15	1000	2	95	100	After turning & cleaning
	5-8	2740	2.5	100	89	After turning & cleaning
	½-5	1000	3	93	0	
	4-5	1000	3	100	100	
	1-14	1000	3		56	Floury: Lesser grain borer
	1-15	1000	3		100	
	5-9	2740	3		86	
	7-11	2740	3		92	
	8-10	2740	3		81	
	9-1	2740	3	83		
	10-1	2740	3	79		
	10-2	2740	3	78		
	5-10	5000	3.6		91	
	2-12	1000	4	69	60	
	3-12	1000	4	92	100	
	4-12	1000	4		98	
	9-9	1500	4		100	
	9-4	2740	4		99	
	9-5	2740	4		100	
	10-4	2740	4		100	
	11-4	2740	4		100	
	11-5	2740	4		94	
	8-4	2740	4		86	
	11-3	2740	6		93	

Table 15:--Effect of various fumigants on adults and eggs of stored grain insects, Hutchinson, Kansas, October, 1943.

Fumigant	Dosage per 1000 bu. (gal.)	Bin No.	Mortality percent: Adults	Mortality percent: Eggs
1000-bushel bins				
Chloropicrin, 2# in carbon tetrachloride to make 1 gallon	1.5	1-16	100	100
	1.5	2-16	100	100
Dowfume Br-10	2	2-13	100	100
	2	9-13	100	100
Carbon tetrachloride	3	2-8	100	100
	3	2-9	100	100
Acrylonitrile-trichloroacetonitrile-carbon tetrachloride 1:1:18	2	1-8	99	100
	2	3-4	100	100
B-methylallyl chloride-carbon tetrachloride 1:3	1.5	1-6	98	100
	1.5	1-7	100	100
Ethylene dichloride-carbon tetrachloride 3:1	4	2-12	69	100
	4	3-12	92	100
	3	4-5	100	99.7
	3	½-5	98	100
Ethylene dichloride	4	2-4	94	99
	4	2-5	82	76
Carbon disulphide-carbon tetrachloride 1:4	3	3-8	100	67
	3	3-9	100	100
Propylene dichloride	4	3-6	38	78
	4	3-7	63	46
Ethide 2# in carbon tetrachloride to make 1 gallon	1.5	2-6	96	66
	1.5	2-7	100	50
Control		5-1		23
2740-bushel bins				
Ethylene dichloride-carbon tetrachloride 3:1	3	9-1	83	89
	3	10-1	79	85
	3	10-2	78	71
Control		5-1		11

Determination of the Efficiency of Fumigants on Native Populations

In determining the efficiency of fumigants in reducing indigenous insect populations in stored grain, it has been the custom to take one average sample from the bin before and another after fumigation. The percent kill was computed on the basis of the difference in infestation between the two samples.

Occasionally, however, a sample taken after fumigation contained a greater insect population than that taken before fumigation. For this reason, it was evident that a single sample was inadequate for the determination of mortality in natural populations. In order to get information on the number of samples required to give a fairly reliable estimate of the mortality resulting from fumigation, a series of samples was drawn from a bin before fumigation, and another series after fumigation. The variation in samples taken before fumigation is given in table 13. The results from five samples taken after fumigation are presented in table 16.

If the lowest population estimate before fumigation chanced to be paired with the largest estimate after fumigation, and, if the largest estimate before fumigation happened to be paired with the smallest estimate after fumigation, the estimated mortality could have ranged from 61 to 97 percent. Manifestly, single samples taken before and after fumigation cannot be expected to give a sufficiently accurate estimate of the mortality in natural populations in the determination of minimum effective dosages of fumigants.

Table 16:--Number of stored grain insects found in average samples taken after fumigation from Bin 8-4, Hutchinson, Kansas, Dec. 10, 1943.

Sample No.	Number insects per probe										Ave. per 1000 grams
	Center		North		East		South		West		
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	
1	0	16	0	1	0	0	0	0	0	0	1.7
2	0	1	1	6	0	0	0	31	0	0	3.9
3	0	3	0	2	0	3	0	0	0	0	0.8
4	0	24	0	6	0	0	0	0	0	0	3.0
5	0	14	1	3	0	0	0	13	0	1	3.2
Total	0	58	2	18	0	3	0	44	0	1	2.5
Per cent of total	0	46.0	1.6	14.3	0	2.4	0	34.9	0	0.8	
Mean	0	11.6	0.4	3.6	0	0.6	0	8.8	0	0.2	

Total number living insects-- 126

The next step was to draw at random, five groups of 5 samples each from the 25 samples taken before fumigation. These were then paired with the five samples taken after fumigation, as listed below:

Sample number	Number of insects: Before fumigation	Number of insects: After fumigation	Mortality percent
Group 1			
13	101	17	83
2	182	39	78
10	202	8	96
14	156	30	80
19	209	32	85
		Mean	84
Group 2			
2	182	17	89
6	139	39	72
3	245	8	97
18	195	30	85
15	267	32	88
		Mean	86
Group 3			
14	156	17	89
23	129	39	67
7	248	8	97
18	195	30	85
11	223	32	86
		Mean	85
Group 4			
16	172	17	90
7	248	39	84
2	182	8	90
21	113	30	73
13	101	32	68
		Mean	81
Group 5			
4	174	17	90
8	126	39	69
21	113	8	93
3	245	30	88
12	129	32	75
		Mean	83

On the basis of 5 average samples before and after fumigation the mortality ranged from 81 to 86 percent with a mean of 84 percent as compared with a mean of 83.9 $\pm$ 1.6 and a standard deviation of 8.1, when the 25 samples were treated as a single group.

Five groups of 3 samples each were then drawn at random as follows:

	Before fumigation		After fumigation		Mortality
	Sample No.	No. insects	Sample No.	No. insects	percent
Group 1	3	245	3	8	97
	24	144	4	30	79
	1	210	1	17	92
				Mean	89
Group 2	7	248	4	30	88
	4	174	3	8	95
	9	201	5	32	84
				Mean	89
Group 3	5	254	4	30	88
	18	195	1	17	92
	2	182	3	8	90
				Mean	90
Group 4	15	267	5	32	88
	8	126	2	39	69
	18	195	1	17	88
				Mean	82
Group 5	14	156	5	32	79
	17	166	1	17	90
	13	101	4	30	70
				Mean	80

On the basis of 3 average samples before and after fumigation, the mortality ranged from 80 to 90 percent, with a mean of 86.

It is therefore concluded, that 3 samples taken before fumigation and a like number after fumigation will give a reasonably accurate estimate of the mortality in natural populations, and at the same time take into consideration the great amount of labor required in obtaining the samples. In the future, mortalities in natural populations will be determined on this basis.

Retention of Fumigants in Wheat Stored in Steel and Wood Bins

Mention has been made in several previous reports of the length of time that fumigants are retained in lethal concentrations in grain stored in steel bins. These observations have been continued during the past quarter. Check probes containing living stored grain insects were put in the bins 6 or 7 days after fumigation. These were removed one week later, and the mortality noted. Fresh probes were put in at weekly intervals until the mortality reached the control value. The length of time that various fumigants are retained was found to be as indicated below:

Carbon tetrachloride, 2 gals. per M bu., 1000 bu. steel bins	2 to 3 weeks
Carbon tetrachloride, 3 gals. per M bu., 2740 bu. steel bins	4 to 5 weeks
B-methylallyl chloride, 2.5 lbs. per M bu., 1000 & 2740 bu. steel bins	2 to 3 weeks
Chloropicrin, 2 lbs. per 1000 bu., M bu. steel bins	4 to 5 weeks
Chloropicrin, 3 lbs. per 1000 bu., M bu. steel bins	10 to 12 weeks
Ethide, 2 to 3 lbs. per 1000 bu., M bu. steel bins	4 to 5 weeks
3-1 mixture, Ethylene dichloride-carbon tetrachloride	
3 gals. per M bu., 1000 bu. steel bins	4 to 5 weeks
3 gals. per M bu., 5000 bu. sealed steel bins	24 to 32 weeks
4 gals. per M bu., 1000 bu. steel bins	6 to 8 weeks
4 gals. per M bu., 2740 bu. steel bins	12 to 16 weeks
6 gals. per M bu., 2740 bu. steel bins, high dockage	24 to 28 weeks
5 gals. per M bu., 1500 bu. wood bins	5 to 6 weeks
1-4 mixture, carbon bisulphide-carbon tetrachloride	
2 gals. per M bu., 1000 bu. steel bins	3 to 4 weeks
2 gals. per M bu., 2740 bu. steel bins	3 to 4 weeks
3 gals. per M bu., 2740 bu. steel bins	4 to 5 weeks
4 gals. per M bu., 1500 bu. wood bins	2 to 3 weeks

Effect of Fumigation on the Viability of Wheat Stored in Tight Steel Bins

The discovery that fumigants are retained in stored grain for long periods of time led to a study of the effect on viability of such long exposures.

At Hutchinson, germination tests have been made periodically following fumigation with various materials, extending over a period of from 1 to 16 weeks. These tests revealed that there were great differences in the effect on viability in different lots of grain treated with the same fumigant. The average change in percent germination for the lots of grain treated with several fumigants is listed below:

Fumigant	No. of bins	Mean change in viability percent
1. Ethide-carbon tetrachloride mixture	14	-27.4
2. Chloropicrin-carbon tetrachloride mixture	15	-26.8
3. Chloropicrin-ethylene dichloride mixture	2	-23.5
4. Carbon bisulphide-carbon tetrachloride mixture	4	-16.2
5. Carbon tetrachloride, alone	9	-14.6
6. B-methylallyl chloride-carbon tetrachloride mixture	16	-10.1
7. Acrylonitrile-trichloroacetonitrile-carbon tetrachloride mixture	13	- 3.4
8. Ethylene dichloride-carbon tetrachloride mixture	2	+ 2.5

It should be borne in mind that this phase of the work is still in progress, and that the above figures serve only to indicate trends and may have to be revised in the light of later work.

At Jamestown, a series of 9 bins has received an annual fumigation with a 3-1 mixture of ethylene dichloride and carbon tetrachloride containing 10% methyl bromide. The first fumigation was given in November, 1941; the second in August, 1942; and the third in September, 1943. An equal number of the same types of bins have received no treatment during the entire storage period. Germination tests have been run for both series of bins at intervals of about three months since the bins were filled in July, 1941. The results are given in table 17.

In all of the fumigated bins, there has been a decided decrease in the viability of the grain, an average of 69 percent in 2740-bu. bins, and 53 percent in 1000-bu. bins. It will be noted that the decrease in viability was not as rapid in 1000-bu. bins as in the larger bins, even though all of the bins received the same dosage of fumigant (2 gals. per 1000 bu.). This difference is probably due to the shorter time that the fumigant is retained in 1000-bu. bins.

In the series of bins which received no fumigation, the average decrease in germination was 8.6 percent in 2740-bu. bins, and 2.5 percent in 1000-bu. bins.

Table 17: -- Effect of fumigation on the viability of wheat stored in steel bins, Jamestown, North Dakota.

Bin No. and capacity	Percent germination, fumigated bins: Aug. 1941	Feb. 1942	Aug. 1942	Nov. 1942	Feb. 1943	May 1943	Aug. 1943	Total change
2740 bu.								
R-1	94	92	65	36	24	20	16	-78
R-2	89	70	56	26	30	14	17	-72
S-1	92	72	60	44	44	32	30	-62
P-5	87	82	72	50	48	22	28	-59
Q-5	91	89	55	28	28	20	17	-74
R-5	93	84	61	53	51	38	17	-76
S-4	94	85	74	58	56	56	32	-62
Average	91.4	82.0	63.3	42.1	40.1	28.9	22.4	-69
1000 bu.								
G-5	90	90	84	70	73	60	42	-48
H-5	94	96	90	39	41	31	36	-58
Average	92.0	93.0	87.0	54.5	57.0	45.5	39.0	-53
Unfumigated Bins								
2740 bu.								
J-4	90	90	84	84	81	88	87	-3
K-4	95	90	93	89	90	90	86	-9
K-5	94	92	86	90	93	92	87	-7
P-4	93	90	83	--	88	80	83	-10
Q-4	90	92	--	--	92	88	84	-6
R-4	93	92	--	--	90	88	80	-13
S-3	93	87	79	--	88	86	80	-13
Average	92.6	90.4	83.0	87.7	88.9	87.4	84.0	-8.6
1000 bu.								
G-4	90	82	--	80	85	86	83	-7
H-4	91	92	--	85	90	89	93	+2
Average	90.5	87.0	--	82.5	87.5	87.5	88.0	-2.5

Effect of Fumigants on Germination and Baking and Milling Qualities of Wheat*

As stated in Report No. 9, pp. 13-16, samples of 10.5%, 12.5%, and 14% moisture wheat were fumigated for 24 hours with methyl bromide, chloropicrin hydrocyanic acid, carbon disulfide, carbon disulfide - carbon tetrachloride 1-4 mixture, Ethide - carbon tetrachloride mixture, chloropicrin - carbon tetrachloride mixture and ethylene dichloride - carbon tetrachloride-methyl bromide mixture to determine the effect of these fumigants on the germination, and the correlation if any between germ damage and baking quality.

All tests were made under laboratory conditions. One lot of each sample was aerated after fumigation and stored in a cotton bag so that aeration would continue, while the companion lot of each sample was held in a tightly sealed container in which it was fumigated. Samples were taken at monthly intervals for germination tests, baking tests, etc.

Germination data for all samples of the three different moisture wheats, are given in tables 18, 19, and 20, covering a period of 4 months after the initial fumigation.

Table 18: -- Effect of fumigants on germination of wheat as influenced by dosage, grain moisture, length of exposure, etc.

Fumigant and dosage per 1,000 bushels		Percentage of germination of 10.5% moisture wheat							
		Not Aerated				Aerated			
		1 Month	2 months	3 months	4 months	1 Month	2 months	3 months	4 months
Methyl bromide	40 lbs.	2					2	3	5
Chloropicrin	40 lbs.	3					3	2	2
Cyanogas	15 lbs.	97	96	99	92	97	96	98	96
Dowfume 75	6 gals.	96	95	94	92	95	93	92	93
Carbon disulphide	3 gals.	95	94	96	95	95	96	97	94
Carbon disulphide + CCl_4	3 gals.	93	95	94	91	97	98	97	92
" " " "	6 gals.	89	96	86	96	95	97	90	95
Ethide + CCl_4	1 gal.	93	91	93	92	96	95	96	93
Chloropicrin + CCl_4	1 gal.	76	82	85	84	96	91	94	92
Dowfume Br 10	2 gals.	91	87	97	84	94	96	97	96
Check						96	94	97	98

* Reported by R. T. Cotton and J. C. Frankenfeld in cooperation with the Milling Department of Kansas State College.

Table 19:--Effect of fumigants on germination of wheat as influenced by dosage, grain moisture, length of exposure, etc.

Fumigant and dosage per 1,000 bushels		Percentage of germination of 12.5% moisture wheat							
		Not aerated				Aerated			
		1 Month	2 months	3 months	4 months	1 Month	2 months	3 months	4 months
Methyl bromide	40 lbs.	0					0	0	0
Chloropicrin	40 lbs.	10					4	11	9
Cyanogas	15 lbs.	92	96	96	92	94	96	97	94
Dowfume 75	6 gals.	93	91	96	91	94	95	96	94
Carbon disulphide	3 gals.	87	89	88	84	94	94	95	95
Carbon disulphide + CCl_4	3 gals.	95	95	95	95	95	92	94	95
" " "	6 gals.	87	90	92	90	95	95	94	96
Ethide + CCl_4	1 gal.	93	87	90	82	96	92	92	95
Chloropicrin + CCl_4	1 gal.	78	86	76	74	89	92	94	92
Dowfume Br 10	2 gals.	75	84	82	83	93	88	94	91
Check						98	95	94	94

Table 20:--Effect of fumigants on germination of wheat as influenced by dosage, grain moisture, length of exposure, etc.

Fumigant and dosage per 1,000 bushels		Percentage of germination of 14% moisture wheat							
		Not aerated				Aerated			
		1 Month	2 months	3 months	4 months	1 Month	2 months	3 months	4 months
Methyl bromide	40 lbs.	0					0	0	0
Chloropicrin	40 lbs.	10					11	20	13
Cyanogas	15 lbs.	92	95	95	93	95	95	95	93
Dowfume 75	6 gals.	90	94	92	89	93	97	95	93
Carbon disulphide	3 gals.	77	81	87	66	93	94	94	93
Carbon disulphide + CCl_4	3 gals.	86	90	86	84	92	95	96	92
" " "	6 gals.	79	94	84	66	93	96	98	89
Ethide + CCl_4	1 gal.	82	91	82	64	93	95	94	89
Chloropicrin + CCl_4	1 gals.	39	38	38	33	64	66	77	65
Dowfume Br 10	2 gals.	61	82	77	49	92	93	93	90
Check						89	95	92	88

It will be noted from the data of tables 18, 19, and 20 that where the samples were aerated 24 hours after fumigation, normal dosages of the fumigant showed no injury to germination after a storage period of 4 months except in the case of 14% moisture wheat treated with a mixture of chloropicrin and carbon tetrachloride. In this case germination was reduced to 65%.

In the non-aerated samples slight injury was caused to germination by Dowfume Br 10 and the chloropicrin - carbon tetrachloride mixture where the grain moisture was 10.5%, by Ethide, Dowfume Br 10 and the chloropicrin - carbon tetrachloride mixture where the grain moisture was 12.5% and fairly severe injury by carbon disulphide, Ethide, carbon disulphide - carbon tetrachloride mixture, Dowfume Br 10 and the chloropicrin - carbon tetrachloride mixture, when the grain moisture content was 14%.

Objectionable odor was noticeable in loaves from the non aerated wheat treated with Cyanogas and carbon disulphide and in loaves from aerated wheat treated with heavy dosages of methyl bromide and chloropicrin. Loaf volume was distinctly decreased where wheats were fumigated with heavy dosages of methyl bromide and chloropicrin but this appears to be correlated with the residual chemicals rather than the loss in germination. In the case of the one sample of 14% grain fumigated with the chloropicrin-carbon tetrachloride mixture the marked loss in germination may be correlated with the loss in loaf volume.

Fumigation with carbon disulphide apparently causes an increase in loaf volume although further tests will have to be made before definite conclusions can be drawn.

It should be noted that in the case of the samples of wheat fumigated with the heavy dosages of methyl bromide and chloropicrin, that the chemicals were absorbed and retained by the endosperm, and flour milled from wheat after 3 months aeration, contained very heavy residues. In the case of the 12.5% moisture wheat treated with methyl bromide, the bromine residue in the flour was 1087 parts per million.

Under laboratory conditions the severe injury to wheat germination observed, in the Hutchinson and Jamestown experiments, as a result of long time exposure to normal dosages of certain fumigants, was not apparent. This would indicate that laboratory tests are not comparable with field conditions and should not be relied upon without corroboration by field tests.

Table 21: -- Baking values of wheat samples 3 months after initial exposure to fumigation.

Dosage of fumigant per M bushels	Grain moisture	Flour protein [1] %	Flour ash [1] %	Mixing time Mins.	Absorption 15% M.B. [1] %	Loaf volume [2] cc	Crumb color [3]	Texture grain [4]
Samples aerated after 24 hours' exposure								
40 lbs. methyl bromide	12.5	10.8	.45	3.3	62	676	80cy	83-o
40 lbs. chloropicrin	12.5	10.8	.43	3.3	62	715	80cy	80-o
15 lbs. Cyanogas	12.5	10.8	.41	3.3	62	800	80cy	83-c
3 gals. carbon disulphide	12.5	10.9	.45	3.3	62	822	80cy	83-c
3 gals. CS_2 - CCl_4 (1-4) mixture	12.5	10.8	.46	3.3	62	814	80cy	83-c
6 gals. " " " "	12.5	10.8	.44	3.3	62	795	80cy	83-c
1 gal. (3# Ethide in CCl_4 to make 1 gal.)	12.5	10.9	.42	3.3	62	804	80cy	83-c
1 gal. (3# chloropicrin in CCl_4 to make 1 gal.)	12.5	11.0	.44	3.3	62	797	80cy	83-c
6 gals. Ethylene dichloride - CCl_4 (3-1) mixture	12.5	10.8	.43	3.3	62	793	80cy	83-c
2 gals. Dowfume Br 10	12.5	10.9	.42	3.3	62	788	80cy	83-c
Check	12.5	11.0	.42	3.3	62	797	80cy	83-c
Samples not aerated								
15 lbs. Cyanogas	12.5	10.8	.41	3.3	62	810	80cy	83-c
3 gals. CS_2	12.5	10.9	.45	3.3	62	795	80cy	83-c
3 gals. CS_2 - CCl_4 (1-4) mixture	12.5	10.8	.46	3.3	62	814	80cy	83-c
6 gals. " " " "	12.5	10.8	.44	3.3	62	779	80cy	83-c
1 gal. (3# Ethide in CCl_4 to make 1 gal.)	12.5	10.8	.42	3.3	62	781	80cy	83-c
1 gal. (3# chloropicrin in CCl_4 to make 1 gal.)	12.5	10.9	.44	3.3	62	788	80cy	83-c
6 gals. ethylene dichloride - CCl_4 (3-1) mixture	12.5	10.8	.44	3.3	62	776	80cy	83-c
2 gals. Dowfume Br 10	12.5	10.9	.44	3.3	62	785	80cy	83-c
1 gal. (3# chloropicrin in CCl_4 to make 1 gal.)	14.0	10.9	.43	3.3	62	774	80cy	83-c
Check untreated	12.5	11.0	.42	3.3	62	797	80cy	83-c

1/ 15% moisture basis

2/ Av. of (3 x 2) loaves

3/ cy = creamy yellow

4/ o = open; c = close

Baking method: malt - phosphate - bromate plus 3% shortening.

Effect of the Amount of Dockage on the Ability of T. confusum to Survive and Reproduce in Wheat of Various Moisture Content*

In previous tests it was shown that the amount of dockage in wheat was a very important factor in the reproduction of T. confusum. It was also shown that dockage had little or no effect on the survival of adults, except in dry wheat. These earlier tests were all conducted at a constant temperature of 80°F. To further check upon the above conclusions, as well as to study the effect of different temperatures, two series of tests were set up, using the same moisture variant wheats namely 9, 12 and 15 percent, and the same varying amounts of dockage, namely clean wheat, wheat plus 0.5% dockage, wheat plus 1.0% dockage, wheat plus 2.0% dockage, wheat plus 4.0% dockage and wheat plus 8.0% dockage. One series was held at a constant temperature of 85°F. The weekly survival of adults and the number of progeny produced are summarized in tables 22 and 23.

In the series held at a constant temperature of 75°F. there is no significant difference in the percentage of survival in the various moisture dockage varient lots, except in the clean wheat in the 9% moisture lot. In this lot, the percentage of survival after 14 weeks was 81%. In all of the other lots a high percentage of survival is noted. The results from these tests at 75° F. agree with those conducted at 80° F. in that neither the dockage nor the moisture content of the wheat is significant from the standpoint of survival of adult T. confusum.

Reproduction in general follows the same pattern as was true for the series conducted at 80° F. That is, at a given moisture content, the amount of reproduction increases as the amount of dockage is increased, and increases as the moisture content of the wheat is increased. The deviation from this rule in the 4 and 8 percent dockage lots in the 12% moisture series, does not lend itself to any plausible explanation.

In the 85° F. constant temperature series, an inconsistent variation in the percentage of survival is noticed in dockage lots of all three moisture variant series. In the 9 and 12 percent moisture series the percentage of survival is greatly reduced in practically all dockage lots, but in no consistent or progressive order. In the 15% moisture series the percentage of survival is fairly high in the clean wheat and the wheat with 0.5%, 1% and 2% dockage, but drops off decidedly in the 4 and 8 percent dockage lots. The only plausible explanation for this variation in survival is that at 85°F. we have apparently exceeded the optimum temperature for longevity of this species, and the factor of individual tolerance to high temperature is beginning to operate. This assumption is somewhat substantiated by the fact that in practically all of the lots where the percentage of survival is low, greatest reduction in survival occurred during the early period of the time that the tests were in progress. That is, the greatest reduction in the percentage of survival occurred during the 4th, 5th and 6th week. After this initial reduction very little further reduction in survival resulted.

Reproduction rate follows the same trend as survival. However, assuming that the surviving adults were equally divided as to sex, the same general theory, that reproduction increases as the moisture and dockage is increased, would hold true. Since the only means of determining the sex of adult T.confusum is by dissection of sex organs, the above statement would at best be a guess.

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* Contributed by R. T. Cotton and J. C. Frankenfeld.

Table 22: -- Survival and reproduction of T. confusum in 9, 12, and 15% moisture wheat with varying percentages of dockage at 75° F.

Rearing medium	Percentage of survival after													No. of progeny
	1 Week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks	11 weeks	12 weeks	13 weeks	14 weeks	
9% Moisture Wheat															
Clean wheat berries	98	97	97	94	91	89	89	87	87	87	83	81	81	81	1
Same plus 0.5% dockage	99	98	96	95	95	94	92	92	91	91	90	90	90	90	0
" " 1.0% "	99	97	97	97	95	95	95	95	95	95	95	95	94	94	2
" " 2.0% "	99	98	96	96	96	95	95	94	93	93	93	93	93	92	3
" " 4.0% "	99	98	97	97	97	96	96	96	95	95	94	93	93	93	24
" " 8.0% "	100	100	100	99	99	99	99	99	99	99	99	99	99	99	159
12% Moisture Wheat															
Clean wheat berries	100	100	100	100	100	99	99	98	97	97	97	97	97	96	0
Same plus 0.5% dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	14
" " 1.0% "	100	100	100	99	98	97	97	97	96	96	95	95	95	95	48
" " 2.0% "	100	100	99	99	99	99	99	99	99	99	99	99	98	98	118
" " 4.0% "	100	100	98	98	98	97	97	94	94	93	93	93	93	93	35
" " 8.0% "	100	100	100	100	100	100	100	93	93	91	91	91	91	90	65
15% Moisture Wheat															
Clean wheat berries	100	100	100	100	100	100	99	99	99	99	99	99	98	98	18
Same plus 0.5% dockage	100	100	100	100	100	99	99	99	99	99	99	99	99	99	95
" " 1.0% "	100	100	100	100	99	99	99	99	99	99	99	99	99	99	122
" " 2.0% "	100	100	100	100	100	98	98	98	98	98	98	98	98	98	175
" " 4.0% "	100	100	100	100	100	99	99	99	99	99	99	99	98	98	271
" " 8.0% "	100	99	99	99	98	98	98	98	97	97	97	97	96	96	490

Table 23: -- Survival and reproduction of *T. confusum* in 9, 12, and 15% moisture wheat with varying percentages of dockage at 85° F.

Rearing medium	Percentage of survival after															No. of progeny
	1 Week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks	11 weeks	12 weeks	13 weeks	14 weeks	15 weeks	16 weeks	
9% Moisture Wheat																	
Clean wheat berries	100	100	100	99	99	95	86	82	66	55	45	34	8	8	7	7	0
Same plus .5% dockage	100	99	99	99	97	97	94	94	92	91	90	90	89	89	85	84	11
" " 1.0% "	100	100	99	99	57	49	46	44	44	44	44	44	44	44	43	43	0
" " 2.0% "	100	100	94	90	85	82	82	82	82	79	77	77	77	77	76	75	0
" " 4.0% "	100	100	86	61	55	54	53	52	52	52	52	51	51	51	50	50	0
" " 8.0% "	100	80	79	76	74	71	67	67	67	67	66	66	66	66	66	65	25
12% Moisture Wheat																	
Clean wheat berries	100	99	99	99	99	99	99	99	98	97	95	92	92	87	80	75	224
Same plus .5% dockage	100	99	99	97	97	97	97	96	96	96	96	96	86	83	75	66	217
" " 1.0% "	100	98	97	69	59	50	50	50	50	50	50	50	49	49	44	42	169
" " 2.0% "	100	95	94	65	63	63	63	58	56	53	50	47	43	41	40	37	297
" " 4.0% "	100	100	99	37	35	35	35	34	34	34	34	33	33	33	33	33	391
" " 8.0% "	100	100	100	85	83	83	83	82	82	82	81	81	77	73	69	66	801
15% Moisture Wheat																	
Clean wheat berries	100	100	99	99	98	98	98	97	97	97	97	96	95	93	93	91	277
Same plus .5% dockage	100	99	99	99	99	99	99	98	98	98	97	97	97	96	96	95	448
" " 1.0% "	100	99	99	99	99	99	99	98	98	96	95	95	94	94	94	93	538
" " 2.0% "	100	99	99	97	93	93	93	93	93	93	93	93	92	91	90	90	394
" " 4.0% "	100	99	99	68	58	57	57	57	57	57	57	57	57	57	57	57	434
" " 8.0% "	100	100	99	70	63	63	63	63	63	63	63	63	63	63	63	62	729

Effect of Lack of Moisture on the Breeding of the Flour Beetle*

It has been noted that the flour beetle, Tribolium confusum, will breed in dry grain if grain dust or broken kernels are present. Just how dry the grain can be and still be favorable for reproduction is indicated by experimental work in which the flour beetle was reared in a desiccator in flour from which the moisture had nearly all been removed.

A series of tests were started using 8 lots of 50 adult beetles (25 females and 25 males) each. Lots numbered 1 to 4 consisted of adults which had been confined in a desiccator for 3 months prior to the beginning of this series of tests. Lots numbered 5 to 8 consisted of adults which had transformed from pupae during the week prior to the beginning of these tests.

The flour used in the tests was dried in an electric oven until the moisture content had been reduced to 0.03%. Ten grams of this flour was placed in each of eight petri dishes, which were kept confined in a desiccator over crystals of calcium chloride. After the flour had been confined in the desiccator for one week, T. confusum adults were introduced.

At daily intervals over a period of three weeks, the flour was sifted to remove any eggs which may have been laid. At the end of 21 days, the number of eggs recovered from the lots numbered 1 to 8, were 322, 262, 266, 245, 523, 433, 489, and 469 respectively. It is interesting to note that adults which had been confined in dry flour for three months, that is, adults in lots No. 1 to 4, continued to lay eggs, although the total number was considerably less than the number laid by the newly emerged adults.

In a previous test it was shown that an average of 73% of the eggs of T. confusum hatched when kept in a desiccator, as compared to 85% batch of eggs kept at a relative humidity of 65 to 70%.

To determine whether the larvae of the confused flour beetle are able to complete development in dry flour, five freshly hatched larvae were placed in small shell vials with a small quantity of the dry flour. Only one larva was placed in each vial. These vials were then stoppered with a cotton plug and placed in a desiccator.

The larvae hatched on Sept. 4, and the lid of the desiccator was not removed until Nov. 30. On this latter date each of the five vials contained a fully developed live adult.

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* Contributed by R. T. Cotton and J. C. Frankenfeld.

At the same time that the above 5 larvae were placed in the desiccator 77 larvae were placed in a petri dish with ten grams of dry flour, and kept in the same desiccator. On examination a total of 71 adults were recovered. The moisture content of the flour, in which these 71 larvae had completed development, had increased from 0.03% to 0.57%. This increase in the moisture content of the flour is unquestionably due to the absorption of moisture from the calcium chloride crystals.

In a previous test it was noticed that the moisture content of the flour in which the flour beetles were confined had increased somewhat over what it had been when the test was started. To determine whether this increase was caused by the activity of the flour beetles or the possible absorption of moisture from the calcium chloride crystals, a dish of flour free of insects was kept in the same desiccator containing the oviposition dishes. At the end of three weeks when the oviposition records were discontinued the moisture content of the flour from each of the eight oviposition dishes, as well as the check dishes was determined. The moisture content of the flour in the oviposition dishes varied from 0.421% to 0.434%, and that of the check dish was 0.426%. The original moisture content of the flour was 0.03%. Since the flour in the check dish as well as the flour in the dish containing the developing larvae had never been exposed to an atmosphere other than that of the desiccator, the increase in the moisture content is unquestionably due to absorption of moisture from the calcium chloride.

These tests show that the confused flour beetle can survive, reproduce and develop under extremely dry conditions and in food nearly devoid of moisture.